

**EXHIBIT I**  
**Dated 05/08/01**

**Mars Ascent Vehicle (MAV) Concept Study - Contract Support**

**I DESCRIPTION OF OPPORTUNITY**

**Mars Sample Return (MSR) Technical Approach Study  
(RFP No. JPL-MSR-01 - contracts recently awarded)**

Recently, the Jet Propulsion Laboratory (JPL) awarded contracts for the development of diverse sets of technical approaches and mission concepts for the Mars Sample Return (MSR) mission to be launched in 2011. The MSR mission is defined as “beginning at an Earth launch and ending at the return of a Martian sample to the Earth’s surface”. Under these contracts, each contractor will conduct a Preliminary Technical Approach (Phase 1) Review of the mission at JPL in late July 2001. JPL will select one technical approach for the contractor to study in depth, during Phase 2 of the MSR study contract.

**The Mars Ascent Vehicle (MAV) Concept Study  
(this RFP No. JPL-MAV-01)**

Distinct and separate from the MSR Study is the desire for an industry study of MAV Concepts, which provides for a more definitive level of study than is possible in the broader MSR study described above. JPL, in collaboration with NASA Marshall Space Flight Center (MSFC), has conducted detailed in-house Concept studies for Mars Ascent Vehicles (MAV) for a spectrum of Mars Sample Return architectures. The MAV study general ground rules and assumptions (Table 1) reflect information derived from the previous in-house study and selected output from the MSR study. The additional output regarding viable MSR approaches, in accordance with Article 1, paragraph 3.2 will be made available to the MAV study contractor by JPL on or about 8/01/01 (Table 1).

This contract is to develop MAV Concepts that:

1. Identify state-of-the-art (SOA) technologies for Liquid, Gels, Solid, and Hybrid (Liquid plus Solid Stages) Propulsion Systems that are well suited to MAV applications;
2. Define Research and Technology (R & D) developments that can be made to improve and advance the SOA technologies;
3. Delineate roadmaps for R&D of the advanced propulsion systems to result in flight qualification; and
4. Provide detailed data and assessments on technical, economic, performance, and risk for each of the proposed Liquid, Gel, Solid, and Hybrid MAV concepts.

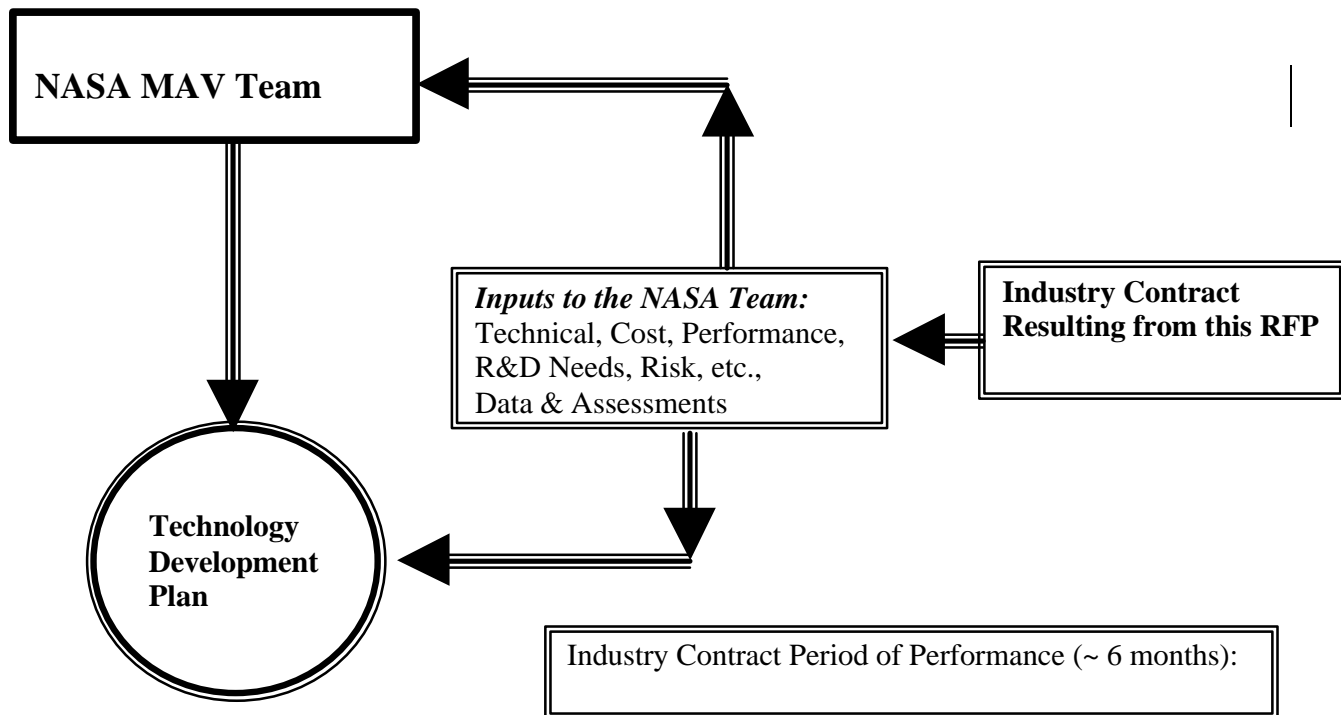
Additional information on NASA's Mars Exploration Program can be accessed at the Internet address <http://mars.jpl.nasa.gov>

## **II. CONCEPT STUDY OPPORTUNITY**

NASA has an objective of bringing Mars surface and/or atmospheric samples (soil, rocks, atmosphere) to Earth for detailed study and analyses. An integral system within the overall mission is the MAV that will lift the packaged Mars samples from the Martian surface so that they may be returned to Earth. As shown in Figure 1, Concept studies are being conducted by JPL and MSFC that include concepts utilizing MAV propulsion systems based on solid, gel, and liquid propellants. Table 2 delineates the ground rules and assumptions for the industry MAV Concepts. Options to be considered include a MAV that will either place the payload into Martian orbit or onto a Mars escape trajectory.

The complete Concept Study space will range from systems evaluations to detailed assessments of MAV propulsion elements

**Figure 1.MAV Concept Study**



Innovations are sought to enhance propulsion capabilities for the Mars Ascent Vehicle (MAV) for functions including primary propulsion from the Mars surface, and orbit insertion. Liquid, Gel, and solid rocket motor propulsion technologies are of interest at the component, sub-system, and system level. Key aims of this Concept study are to identify, assess, and roadmap crucial liquid, gel, and solid propulsion technology advancements which will lead to 1) significant miniaturization; 2) reduced costs in the system components and/or ground servicing; 3) prolonged mission or systems lifetimes; 4) improved reliability; and/or 5) enabling & enhancing mission functions.

**Areas of interest include:**

Propulsion technologies for MAV payloads in the tens to hundreds kilogram class are of interest for the MAV Concept Study. These propulsion concepts should emphasize system simplicity, low power requirements, efficient packaging, and minimize mass, and propellant management components. Industry support is being sought to:

1. Identify and explore areas in which improvements could be obtained (mass, packaging, performance, tolerance to extreme environments, etc,) for the concepts that are determined most viable.

2. Delineate the technology programs that are required to realize specific improvements in these areas.
3. Define the validation approach (testing, demonstration, and/or analyses programs) that is necessary to bring the technologies to the NASA Technology Readiness Level (TRL) 7 or higher, specific to MAV applications in time to for a Critical Design Review to support a 2011 mission.

### **III. CONCEPT STUDY SPACE**

The MAV Concept Study space will include, but not be limited to advanced technologies concerning:

1. Advanced rocket chamber materials for reliable operation in extreme environments. In particular, innovative fabrication technologies including refractory carbide matrix composites and metal-lined composites.
2. Advanced propellant management components. Components should reduce total propulsion system mass and volume, while maintaining or improving reliability and performance of existing chemical components and systems. Components include propellant storage and expulsion devices, propellant feed systems, valves, and absolute isolation devices, flow management and regulation devices.
3. Thermal control hardware for chemical systems.
4. For solid propulsion systems, technologies of interest include high-performance space motors, which can provide reliable propulsion for MAV stages, and for designs, which provide maximum payload capability by using high specific-impulse propellants and advanced materials.

➤ **The MAV areas of study will include but are not limited to:**

1. For identified propulsion systems, improvements available through technologies in MAV launch systems and subsystems (communications, performance, mass definition, etc.)
2. MAV Mars surface operations (reduction in landed mass, reduction in support required from other landed systems, etc)
3. MAV environmental protection
4. MAV Payload attachment/separation system
5. Identification of the high-risk areas of proposed MAV mission concepts and the rationale and approach for risk mitigation.

➤ **The MAV Concept Study parameters will include but are not limited to the following parameters:**

1. Propulsion Options (Solid, Gel, Liquid, & Hybrid)
2. Guidance & Control Options (Autonomous, Intelligent, etc,)
3. MSR Return Options (DR/LEO, DR/DEE, DSR, MOR, etc,)
4. Payload mass

5. Redundancies (Built-in, contrived, etc.)
6. Communication Options (Uplink, Downlink, Data Recording, and Data Dump)
7. Sensitivities of cost, mass, reliabilities, technical readiness, etc

**Table 2.** Mars Ascent Vehicle (MAV) Concept Study:  
General Ground Rules and Assumptions

**1. MAV Description and Functional Definition**

- a. The MAV is responsible for launching a given payload from the surface of Mars (described in 2.).
- b. The MAV team provides no design for the payload.
- c. The MAV provides no orbital maneuvers required for any rendezvous, but is responsible for payload delivery and separation . Separation designs should preclude re-contact of the payload with the spent MAV.
- d. MAV avionics shall provide systems monitoring and data transmission during ascent. Orbiting assets for data reception and earth transmission shall be assumed in place.
- e. MAV avionics and thermal systems shall be robust and, as a minimum, single fault tolerant.
- f. Mass and power contingencies shall be enumerated by specific MAV sub-elements. Apply 5% to heritage components and a 30% to new hardware for mass contingencies and power.

**2. Mission Description:** The MSR mission will launch from Earth on 2011. After up to 90 sols on the Martian surface, the MAV will launch with a given payload to a given target, described below. The various mission profiles will be refined from the results of the Mars Sample Return Technical Approach Study\*.

- a. Mars Orbital Rendezvous (MOR): The MAV target shall be a circular Mars orbit with 500 +/- 100 km radius [To Be Revised (TBR)] and 45 +/- 1 degrees [TBR] inclination. Its payload shall be the sample canister (SC), a 5 kg [TBR] sphere of 20 cm [TBR] in diameter.
- b. Deep Space Rendezvous (DSR): The MAV shall launch a 25 kg [TBR] spherical SC of 35 cm [TBR] to a  $C_3 \approx 1 \text{ km}^2/\text{sec}^2$ .
- c. Direct Return (DR): The MAV target shall be a circular Mars orbit with 500 +/- 100 km [TBR] radius and 45 +/- 1 degrees [TBR] inclination. Its payload shall be the SC and a solar electric propulsion (SEP) stage, used to return the SC from Mars orbit to Earth. The SEP stage shall provide the MAV with G&N, power, and C&DH capabilities. The payload assembly (SC plus SEP) shall be 650 kg [TBR], 200 cm in length, and 90 cm in diameter.

### 3. Entry, Descent and Landing (EDL) Environment and Constraints

- a. MAV volume (packaging) constraints shall be supplied from the results of the Mars Sample Return Technical Approach Study\*. The EDL assembly, including the lander, rover, and MAV, shall fit within an aero-shell no smaller than the one illustrated in figure 2. [TBR].

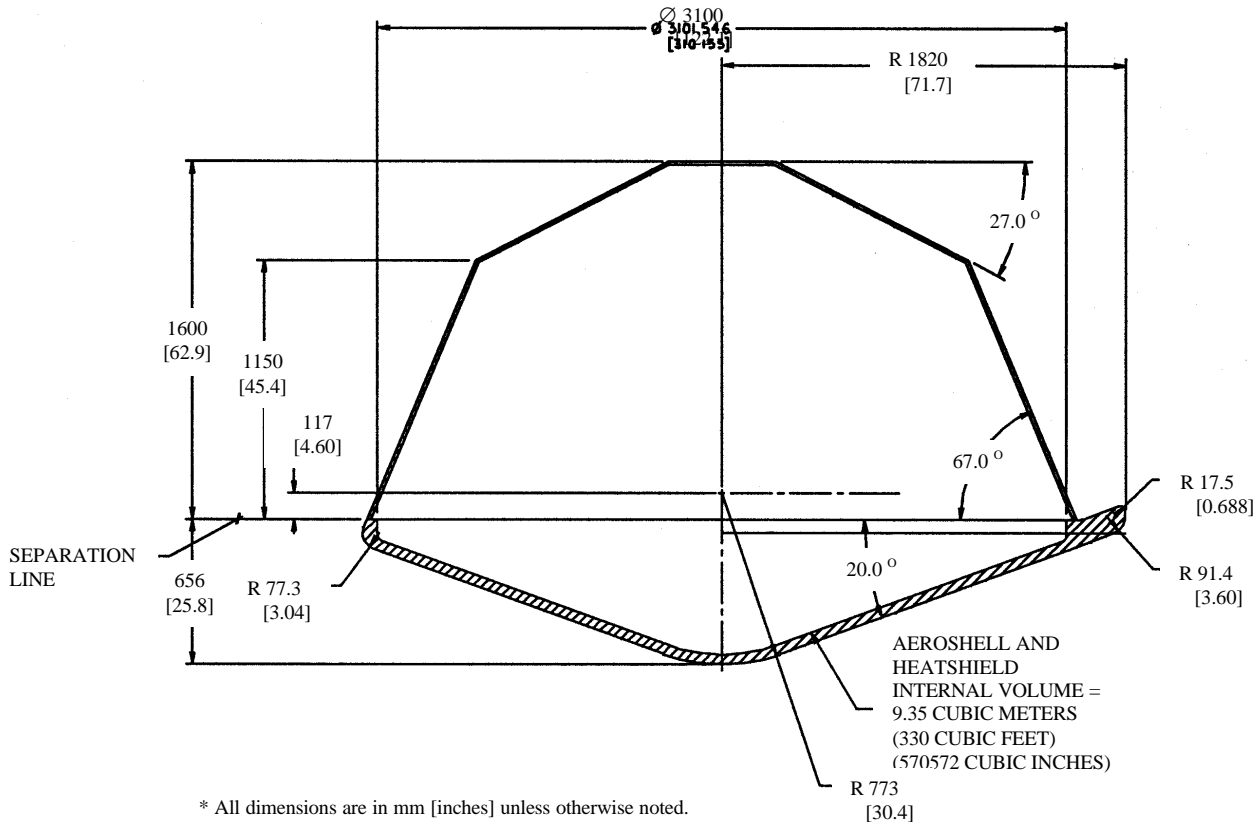


Figure 2. Mars EDL Aeroshell

- b. MAV landed mass constraints shall be supplied from the results of the Mars Sample Return Approach Study\*. The maximum EDL landed mass, including the lander, rover, and MAV, shall be no greater than 2600 kg [TBR].
- c. EDL environment information shall be supplied from the results of the Mars Sample Return Approach Study to be available on or about 08/01/01.

### 4. Launch/Ascent Environment and Constraints

- a. The MAV launch latitude shall be 45 degrees [TBR] north.
- b. The lander platform may be off local horizontal up to +/- 20 degrees [TBR] in any direction.

- c. MAV must withstand Mars environment identified in <http://pds.jpl.nasa.gov>
  - d. Lander is assumed to provide all power to the MAV prior to launch, but concepts are expected to minimize power requirements without unduly penalizing MAV design.
5. **Study Scope:** Though the primary focus of your study should be on MAV propulsion systems, consideration should be given to the following issues with regard to identifying their impacts on your proposed designs and additional requirements that may be imposed on the rest of the MSR system as a results of these impacts.
- a. Thermal: Controlling MAV temperature during surface operations and ascent.
  - b. Mars Environment and Uncertainty: Discussed in 3 and 4 above.
  - c. Lander Interface: Launch support equipment (e.g. thermal igloo, erection mech., blast shielding, etc.), packaging (volumetric constraints (3a), sample transfer, and lander/rover integration), etc.

#### IV. CONTRACTOR GUIDELINES

Contractor shall assess technical, economic, and schedule feasibilities of all state-of-the-art (SOA) technologies, new ideas and approaches for enhanced technical and cost performances, and identification of funds needed for R&D projects. Following elements must be clearly spelled out:

1. For your MAV concepts, what are their merits, shortcomings, and technical fixes?
2. How will the concept selected enhance our ability to achieve highly reliable, low-cost MAVs in terms of Intelligence, Autonomy, and Performance, etc.,
3. What technical, economic, and performance data bases have you collected in order to perform your MAV Concept Study?
4. What are the rationales for your recommendations?

In summary, the Contractor should configure a baseline MAV design using currently available technologies. Essentially this baseline MAV design should answer the question "How would you design the MAV if you had to build it today?".

In addition, to this baseline design, contractor should identify those areas of the design that could be realistically developed within budget and time frame and that could substantially improve the overall MAV design by increasing performance, saving mass, saving money, etc. This enhanced design should answer the question "If you had a given budget and time frame, what technologies would you put money and effort into developing?"